Texas, Arizona and elsewhere, including also two specimens from Alaska. The great majority of the woods have proved to be Angiospermous, and two new genera, with many new species, are attributed to the families Quercineæ, Simarubaceæ, Araliaceæ and Platanaceæ among others.

Several Coniferous trunks of the Pityoxylon, Cupressinoxylon and other types are also described, and the author contributes some interesting diagnostic conclusions respecting a comparison of the structure of the wood of the recent Sequoia and Taxodium with the fossil stems known as Cupressinoxylon. Certain pathological features observed in some of the Coniferous woods, and in one case the presence of a parasitic fungal mycelium, are also noted.

LETTERS TO THE EDITOR.

[The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of NATURE. *No notice is taken of anonymous communications.]*

The Rate of Fall of Fungus Spores in Air.

IN the year 1905 I made what I believe was the first direct test of Stokes's formula for the fall of small spheres in air by using spores liberated spontaneously from the pilei of the mushroom and of allied fungi. The conclusion to which I then came was that the spores of these fungi fall at a rate which is roughly in accordance with Stokes's formula, and this fact was announced by Prof. A. J. Ewart in his translation of Pfeffer's "Physiology of Plants" (vol. iii., 1905, p. 416). The results of further observation were communicated to the Royal Society in 1907 in a paper which I subsequently withdrew.[1]

Recently, Messrs. Zeleny and McKeehan,[2] of the University of Minnesota, have announced that they have made a direct test of Stokes's formula by using lycopodium powder. Their method of measuring terminal velocity consisted in allowing the powder to fall in wide tubes and noting the rate of movement of the centre of the cloud. They came to the conclusion that, for lycopodium spores, the formula gives velocities 50 per cent. in excess of those observed.

In view of the fact that a correct determination of the rate of fall of small spheres in air has now become of considerable importance in connection with the cloud method used by Sir J. J. Thomson and Dr. C. T. R. Wilson for investigations upon the electronic charge, and also because the full details of my experiments will not be published for some months, I have thought it advisable to make a preliminary statement with regard to my methods and results.

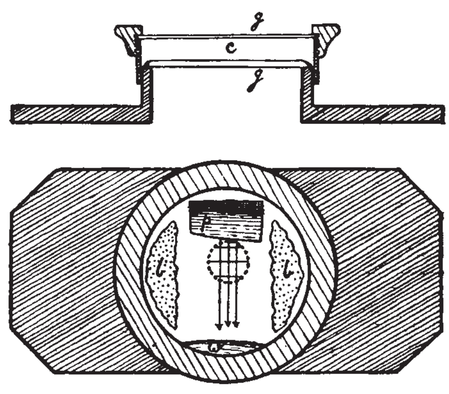
The following equation represents what is known as Stokes's law for the fall of small spheres in a viscous medium:—

$$V = \frac{2}{9}\,\frac{\rho - \sigma}{\mu}\,g a^2,$$

where V = the terminal velocity, ρ the density of the falling sphere, σ the density of the medium, g the acceleration due to gravity, a the radius of the falling sphere, and μ the viscosity of the medium. The new data which were required for testing the law for the fall of small spheres in air by my method were the terminal velocity, the density, and the radius of the fungus spores.

After a considerable amount of preliminary experimentation, the spores of *Amanitopsis vaginata* were chosen for a critical test of Stokes's law, for the following reasons:—(1) they are spherical, except for a tiny "tail," and smooth-coated; (2) they are sufficiently large, so that one can measure their diameters, which are about 10 μ, very accurately; (3) their density is almost that of water, and can be measured within 1 per cent. of accuracy; (4) they can easily be procured.

The average diameter of the spores was obtained by measurements made with the Poynting plate micrometer as applied to the microscope. The density of the spores was determined by the heavy fluid method. Drops containing the spores were placed in the tiny chamber of an apparatus used for counting blood corpuscles, and observations were made as to whether the spores rose or sank in the fluid. The terminal velocity of fall was found in the following manner. A small piece of a pileus of *Amanitopsis vaginata*, including portions of three gills, was placed in a compressor cell in the position shown at p in the accompanying figure. To prevent the falling spores from drying, two pieces of soaked blotting-paper or cotton wool, b, and a drop of water, w, were then added. Upon the cap being adjusted, the piece of fungus became fixed by slight compression and hermetically sealed in the disc-shaped chamber, of which the base and top were of glass (g). The compressor cell was then placed in a vertical position, so that the gills came to look downwards in the natural manner. Thus enclosed in the chamber, the gills continued to rain down spores for some hours. With a horizontal microscope having a magnification of about 25 diameters, a field was focussed just beneath the gills, and the spores were observed crossing the eye-piece



Plan and Section of the Compressor Cell.

lines. In the figure the field is shown by the dotted ring, and the course of three falling spores by arrows.

On viewing the field just below the gills, spores can be seen as distinct, but only just visible, minute, dark objects steadily crossing the field in a vertical direction. Every spore so falling is not in focus, but when the fungus material is in good condition spores in focus come into view at least every five seconds. Convection currents in the tiny chamber are reduced to a minimum, and produce no disturbing effect on one's observations. Even with the minute spores of *Collybia dryophila*, which take about eleven seconds to cross a field 4·55 mm. wide, the direction of fall is vertical, and there is practically no swerving from the course. The records of the velocity of fall of the spores were made with the aid of a large drum, which was driven by electricity, and was provided with a delicate regulator. To the recording fountain pen was attached an electric tapping key, by the depression of which with the finger the passage of each spore across the field of view became recorded on the drum paper. The drum records of the fall of 100 spores served to give the average time taken by the spores in falling a distance of 4·55 mm.

The following table gives a summary of the data obtained in testing Stokes's law. The velocities were the average velocities of 200 spores in Specimen I., of 100 in Specimen II., and of 50 in Specimen III. The densities are doubtless correct to within 1 per cent. The diameters are the average diameters for at least fifty spores. The

[1] The paper, which was partly botanical and partly physical in character, was accepted for publication in the Philosophical Transactions of the Royal Society on conditions which I was unable to accept. This paper, together with other researches, is in course of publication in a book called "Researches on Fungi. The Production, Liberation, and Dispersion of the Spores of Hymenomycetes treated Botanically and Physically, &c." (Longmans, Green and Co.).

[2] "An Experimental Determination of the Terminal Velocity of Fall of Small Spheres in Air." A paper read before the American Association for the Advancement of Science. Abstract in *Science*, March 19.

chamber was closed in each case for half an hour before observations of velocity were made.

Fruit-bodies of fungus	Density of spores	Diameter of spore, in μ	Observed terminal velocity in mm. per sec.	Calculated terminal velocity in mm. per sec. for a sphere with density and diameter equal to those observed for the spores	Actual terminal velocity exceeded calculated by a percentage of
Specimen I.	1·02	11·65	6·07	4·14	47
Specimen II.	1·02	10·19	4·85	3·21	51
Specimen III.	1·02	10·87	5·11	3·64	40

From the results just given it is clear that the figures obtained by observation for the rate of fall of the spores are of the same order of magnitude as those demanded by Stokes's law. However, the law is not confirmed in detail, for, as an average of the three experiments, it was found that the actual velocity of fall of the spores was 46 per cent. greater than the calculated. I have not been able to find any satisfactory explanation for the discrepancy between observation and theory.

My method for testing Stokes's law appears to have various advantages over that used by Zeleny and McKeehan, for the following reasons:—Amanitopsis spores have smooth walls, and are practically truly spherical, whereas lycopodium spores have sculptured walls, and are four-sided. Amanitopsis spores have a diameter only one-third as great as lycopodium spores. In the tube method convection currents cannot be eliminated, and it must surely be somewhat difficult to decide the exact centre of the spore clouds. By my method of using a very small chamber the difficulty of convection currents was reduced so as to be negligible, and the velocities of the individual spores could be measured with considerable accuracy. Amanitopsis spores are liberated spontaneously by the fungus, whereas lycopodium powder requires to be set in motion by artificial means.

In conclusion, I wish to thank Prof. J. H. Poynting for permitting me to carry out the experiments here recorded in the physics department of the University of Birmingham, and also Dr. Guy Barlow for valuable criticism.

A. H. REGINALD BULLER.
The Botanical Department, University of Manitoba, Winnipeg, March 25.

Ionisation by Röntgen Rays.

THE relative ionisations produced in different gases by beams of X-rays have been found by many investigators to depend so markedly on the penetrating power of the X-rays used that no regularity in behaviour has been discovered (see Mr. Crowther's paper "On the Passage of Röntgen Rays through Gases and Vapours," Roy. Soc. Proc., January 14).

Recent experiments which I have made upon homogeneous beams have, however, shown the connection between ionisation, secondary radiation, and absorption in a most striking way. As in the case of absorption phenomena (see letter to NATURE, March 5, Barkla and Sadler), a knowledge of the secondary radiation characteristic of an element is essential and sufficient to explain many of the phenomena of ionisation.

In order to test if such a connection existed, the first substance experimented upon was ethyl bromide—a substance which has been investigated in some detail by Mr. Crowther.

By using homogeneous beams of X-rays, I found that all radiations experimented upon which are not more penetrating than the secondary radiation characteristic of bromine (coefficient of absorption in Al = about 50) produce ionisations which are proportional, or at least approximately proportional, to the ionisation produced by the same beams in air.

When the radiation passed through the vapour was made more penetrating than the radiation characteristic of bromine, the ionisation rapidly increased—that is to say, the ratio of the ionisation in ethyl bromide to that in air rapidly rose to several times its original normal value. It was found to be essential to the production of what may be called the abnormal ionisation simply that the primary radiation be more penetrating than the secondary radiation which bromine emits. This result must be connected with the results of experiments on absorption and secondary radiation.

Thus, when an X-radiation incident on a substance R is softer than the secondary radiation characteristic of R, it is absorbed according to a simple law, the absorption being approximately proportional to the absorption in any other substance in which a characteristic radiation is not excited; it produces no appreciable quantity of this secondary radiation, and it produces what may be called a normal ionisation in R. When the incident radiation becomes more penetrating than the secondary radiation characteristic of R, it is absorbed by an amount greater than given by the law stated; it begins to excite the secondary radiation in R, and it produces an increased ionisation in R. The absorption and ionisation increase to several times their previous value, while the intensity of secondary radiation becomes very great.

As the penetrating power of the incident radiation is increased still further, the absorption by R diminishes, and the secondary radiation excited in R diminishes at the same rate as the ionisation produced by the incident radiation in a thin film of air.

(It should be pointed out that the great increase in ionisation is not due to the secondary radiation.)

In a similar manner, from a knowledge of the secondary X-rays emitted by iodine, the variable behaviour of methyl iodide may be explained. The effects of the lighter elements are comparatively small in all the three phenomena of absorption, secondary radiation, and ionisation.

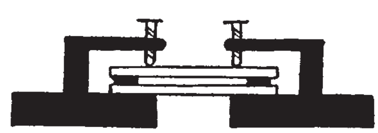
Very many of the apparently complex results, obtained by experiments on the transmission of heterogeneous beams through compound substances, may be explained in terms of a few simple laws which have been obtained by the more fundamental experiments on elementary substances with the use of homogeneous beams.

CHARLES G. BARKLA.
University of Liverpool, April 7.

A Simple Fabry and Perot Interferometer.

DURING a course of experiments with interferometers it was found that a very simple and inexpensive Fabry and Perot instrument could be constructed of plate glass which gives results almost as good as the costly interferometer. The construction of this apparatus for demonstration purposes will well repay the teacher and student. The sharp-coloured interference rings obtained by using luminous gases in vacuum tubes as sources are extremely beautiful. The D lines from a sodium burner are easily separable. If the interference pattern, using a copper or iron arc, is focussed on a wide slit of a single-prism spectrometer, a section of the interference rings is seen in the various spectrum lines, illustrating the method of Fabry and Buisson, and Eversheim, for the determination of the new standard table of wave-lengths. The Zeeman effect can also be easily shown with this apparatus.

Take two pieces of plate glass about an inch square (I have used the so-called German plate) and silver[1] them



until one surface of each plate cuts down the intensity of the transmitted light to about a quarter of the incident light. Separate these silvered surfaces by two strips of cardboard. A useful thickness to begin with is about 0·45 mm., as this will clearly separate the D lines. Mount these plates over a half-inch hole in a metal plate by means of three pressure screws, two of which are shown in the above diagram, being a section through

[1] For silvering solutions see the appendix to Baly's "Spectroscopy."